Managing Fish Predators and Competitors: Deciding when intervention is effective and appropriate

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Abstract- *Fisheries management agencies are increasingly being asked to weigh tradeoffs between game, nongame, native, and nonnative species management. Oregon has recently considered or is considering a variety of activities aimed at protecting and rebuilding depleted native fishes or otherwise improving production of gamefishes. Activities range from reduced harvest restrictions on fish predators and competitors to more aggressive removal programs. Chemical treatment and predator hazing have also been considered for potential benefits to more "desirable" fish populations. This presentation describes a systematic decision-making process to determine for any given case: 1) if predation or competition is likely to be important; 2) if potential predators or competitors can be affected by changes in harvest or with other management actions; and 3) if biological benefits outweigh costs and social/political considerations. This process is applied to several of Oregon's problems to help identify examples where intervention might prove effective and appropriate.*

Introduction

Like most fish biologists, I spent a significant period of time in institutions of higher learning before reaching my current prestigious and highly-paid government position with the Oregon Department of Fish Wildlife. Like most students, I liked some teachers better than others. One of my favorites as a fresh undergraduate at the University of California at Davis was Peter Moyle. Dr. Moyle is an expert on native nongame fishes and fish ecology. The Davis fishery program in general, and Dr. Moyle in particular, taught me to be passionate in the defense of native nongame fishes and critical of game fish management at the expense of native fishes. Now however, in one of life's cruel ironies, I've turned on everything I learned. I may now be one of the least favorite students of my favorite teachers: a blot on an otherwise sterling record. For you see, my first real job was on the Columbia River pikeminnow management program - where people are paid bounties to catch and kill the native nongame fish.

This background has caused me great internal conflicts and I've done a lot of soul searching to reconcile my education with current professional activities. In this paper I'd like to share with you some of my observations and conclusions. I want to take a stab at the "so what?" questions: How do we decide when to intervene in managing one species for the benefit of another? When do we have some hope of reducing predation or competition between some nasty undesirable species and a preferred type? Where should we drop fishing limits, pay bounties, or break out the rotenone? This article describes: 1) The three questions every manager should weigh in considering whether to intervene; 2) Some rules of thumb to help answer the three questions without costing millions of dollars and thousands of lives; and 3) The application of this systematic decision-making process to some real life examples.

The Three Questions

Is it significant, is it affectable, and is it acceptable? These three questions form the basis for a systematic decision-making process for considering when to implement management actions on one species for the benefit of another. Is it significant: Is significant predation or competition occurring? Is species A reducing the productivity of species B directly by eating them or indirectly by outcompeting them for a limited resource? Is it affectable: Can you affect the predator or competitor enough to provide benefits? Can you impede, harass, or remove enough of the right individuals to reduce predation or competition with the desired species? Is it acceptable: Is intervention socially, politically, or legally acceptable? What nonbiological considerations need to be weighed? The answer has to be yes to every one of these questions for intervention to be effective and appropriate (Figure 1). If any one answer is negative, there's probably no point in proceeding further.

It's fairly obvious that there's not going to be a benefit if there's no interaction. But it's also true that even if there is a problem, you're stuck with it if there's no way to reasonably affect the predator or competitor. When El Niño attracts hordes of hungry salmon-eating mackerel to the Pacific Northwest, it's obviously not feasible to rotenone the ocean. Some problems have to be managed around. Likewise if there is a problem and we know how to deal it, a variety of constraints might preclude us from doing so. For instance, even that ocean mackerel situation might be manageable with enough rotenone but some people frown on the indiscriminant distribution of large quantities of chemicals and there's probably some law against it anyway.

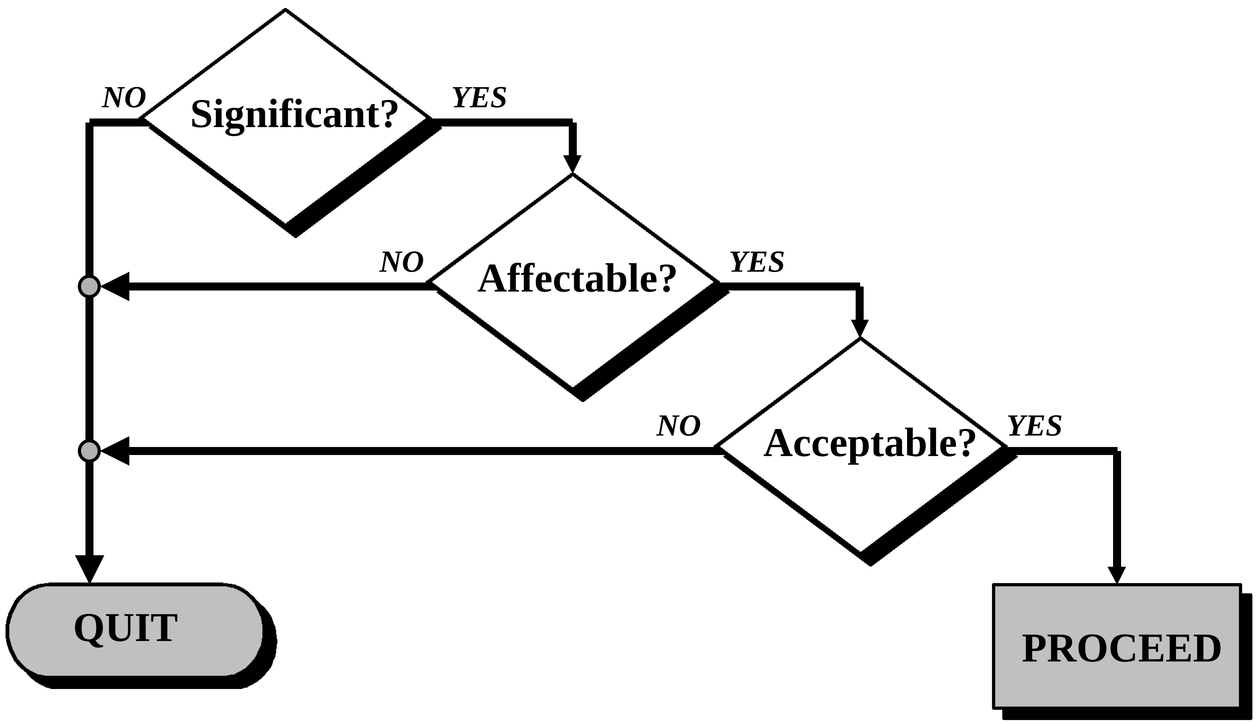

Figure 1. Algorithm for considering intervention in species interactions for the benefit of desirable species.

Rules of Thumb

How can we answer the three questions without the time, money, and staff to conduct in-depth field research on each problem? Species interaction research is extremely time-consuming and expensive and there are three approaches. The ideal method is an empirical approach where you add or remove one species and see if the other responds. For instance, if we want to know if seals and sea lions reduce salmon returns, we could remove all the seals and sea lions and see if we get more salmon. However, populations naturally ebb and flow in response to a whole variety of other factors and so a valid experimental design requires a control to distinguish a response from background noise. And further, we need replicates for the test and control groups for a valid statistical conclusion. Good empirical studies are rare although there have been some excellent case histories where native populations were monitored following a species introduction.

Another method for evaluating species interactions is a mechanistic approach where the relationship is broken into its components, each is evaluated, and then results are added back together. To prove competition, for instance, you would show that both species use the same resource, use by one species precludes use by the other species, the resource is in limited supply, and resource abundance regulates the effected species. For competition, it's generally easy to show common use of a resource but limitation and regulation are extremely difficult to demonstrate. A general problem with mechanistic studies also comes in initially identifying all the appropriate links between cause and effect. You're not testing what you think you are if a key relationship or interaction is overlooked. Mechanistic studies of complicated systems can be likened to trying to put a car engine together when you've never seen one before, you don't have instructions, and you're not even sure you have all the parts.

A third alternative involves drawing useful generalizations from case studies and general ecological principles and then applying those principles to similar cases. These rules of thumb can help infer where problems are likely to occur. Rules of thumb can also help narrow the list of problems and prioritize which ones warrant further action. So let's work through some examples and see if we can develop some generalizations.

The first question in deciding whether to intervene concerns the significance of predation or competition. Let's consider a predation example for pikeminnow on salmon smolts in the Columbia and Willamette rivers (Figure 2). Juvenile salmonids are a significant diet item for pikeminnow from the Columbia River (Poe et al. 1991). Columbia river pikeminnow are estimated to be eating perhaps 16 million salmon and steelhead smolts per year or about 8% of the run (Beamesderfer et al. 1996). Rewards or bounties have been paid for pikeminnow from the Columbia River since 1990 and over 1 million pikeminnow have been dispatched. In contrast, pikeminnow in the Willamette River eat few smolts although large numbers of salmonids migrate through the system (Buchanan et al. 1981). Pikeminnow predation is a problem in the Columbia and not in the Willamette, because the dams have disrupted prey and predator behavior in the Columbia. Predation is low in areas such as the mainstem Willamette where smolts migrate normally: offshore, going with the flow, up in the water column where they avoid the bottom- and shoreline-oriented pikeminnow (Brown and Moyle 1981). This example demonstrates rule of thumb #1: ***Perceived interaction problems are often a symptom of an underlying habitat alteration problem***.

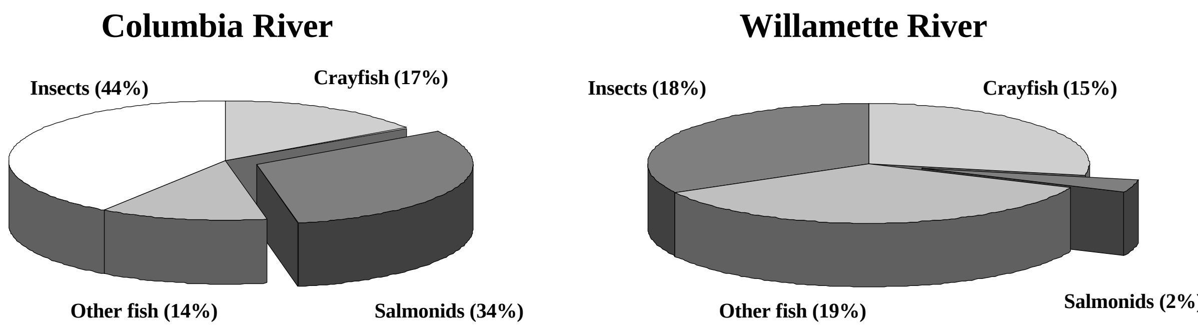

Figure 2. Frequency of occurrence of diet items of northern pikeminnow from the Columbia and Willamette rivers.

Complex interactions in complex communities often compensate and cancel the benefits of intervention. This rule of thumb (#2) is illustrated by a comparison of salmon predation in the Columbia (a large river mainstem) versus Tenmile Lakes (several small coastal lakes). Pikeminnow control is likely to increase salmon production in the Columbia because it is a fairly simple system. Pikeminnow eat smolts on their way from freshwater rearing habitats where density-dependent regulating mechanisms occur to the ocean where survival is largely density-independent (Beamesderfer et al. 1996). If x% of smolts are saved, x% more adults return. However, the food chain is much more complex in Tenmile Lakes. Predators in Tenmile Lakes include bass, bluegill, and bullheads. Coho smolts pass through on their way to the ocean and coho parr also rear in the lakes. Unlike the Columbia, compensatory regulating mechanisms are still operating on coho parr. Predators eat smolts and parr but also eat and compete with each other. The net effect of all these links and feedback mechanisms is extremely difficult to predict. Intervention has a much better chance of working in a simple density-independent community like the Columbia mainstem, than in a complex density-dependent community like Tenmile.

The second question in deciding whether to intervene was: "Can you affect predators and competitors?" Let's reexamine smolt predation in the Columbia River but this time let's compare pikeminnow and walleye. The bigger the pikeminnow, the more smolts they eat (Figure 3). Relatively low exploitation rates amortize through time to reduce survival to large piscivorous sizes. As a result, relatively small annual exploitation rates of only 10-20% should reduce pikeminnow predation by half (Beamesderfer et al. 1996). On a fish per fish basis, walleye are every bit as voracious a smolt predator as pikeminnow. However, walleye eat fewer smolts as they get older and so fishing has relatively little effect on smolt predation by walleye (Beamesderfer and Nigro 1989). Most smolts are eaten by walleye smaller than those caught by anglers and so a walleye bounty or unlimited walleye fishing provides little salmon benefit. Smallmouth bass are similar to walleye in that most predation occurs among bass too small to be affected by fishing (Beamesderfer and Ward 1994). Rule of thumb #3 is: ***Intervention benefits will be small unless you can affect most of the problem animals.***

Another example concerns Tenmile Lakes. In 1968, Tenmile Lake and it's tributaries were chemically treated for bullheads and bluegill. Treatment cost $179,000 1968 dollars and required 755, 50-gallon drums of rotenone (Campbell and Locke 1968, Grenfell and Montgomery 1969). A big spike in coho production immediately followed treatment. However, benefits were short-lived as warmwater fish quickly repopulated (Figure 4). In fact, record bluegill numbers followed their recovery. So not only were treatment benefits short lived for coho, but the recovery spike for warmwater fish might ultimately have depressed coho further than they would have been if we had just left the system alone. But didn't I just get done telling you that intervention in Tenmile Lakes would be confounded by the complex community? Well yes but Tenmile Lakes are very simple communities after rotenone eliminates all the gill-breathing organisms. This chemical simplification is one of the reasons "rehabilitation" produces significant short term results. As usual, this Tenmile Lake example demonstrates a rule of thumb (#4): ***Benefits will be temporary unless you can sustain the effects.***

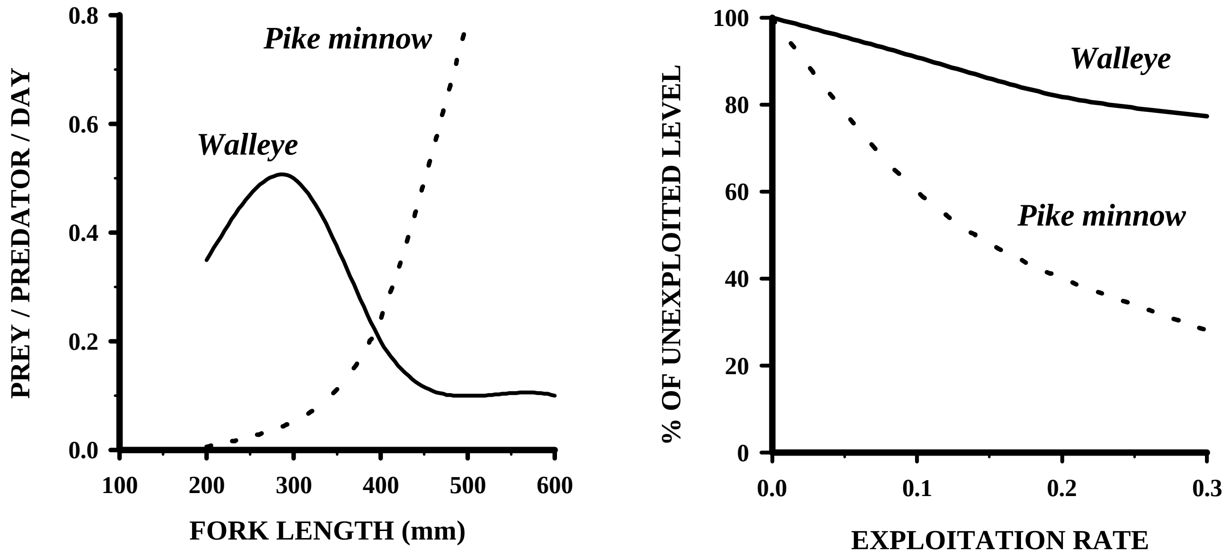

Figure 3. Predation rate on salmonids and the reduction in net predation expected with exploitation of walleye and northern pikeminnow in the Columbia River.

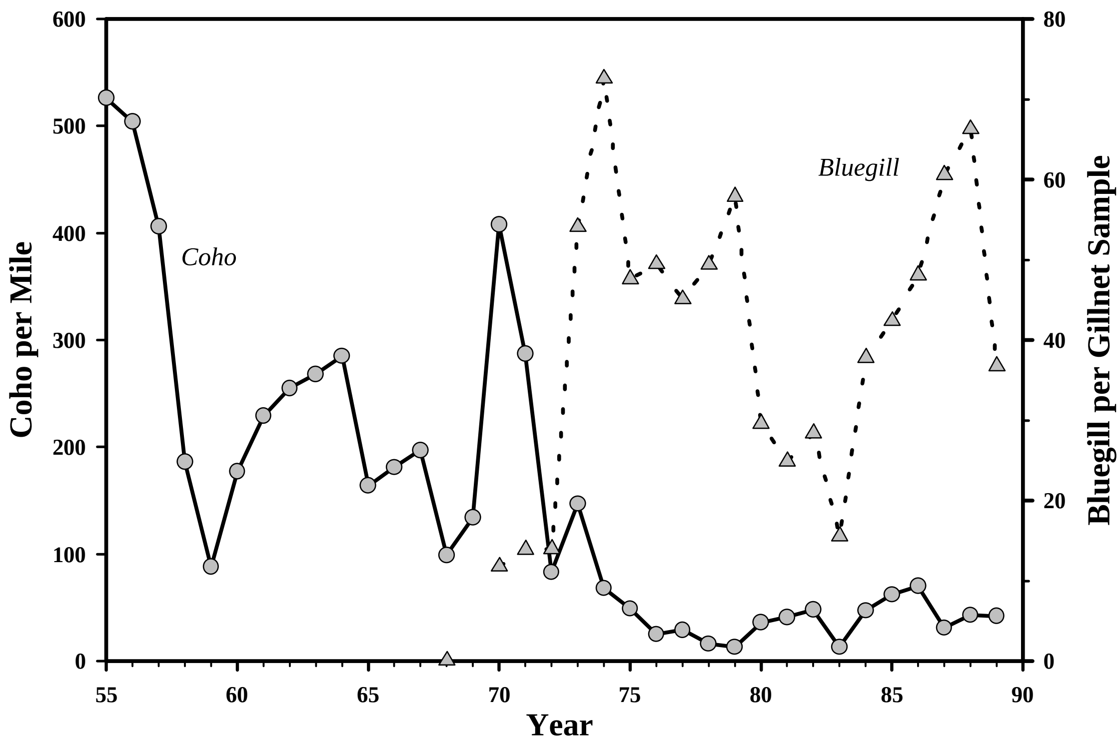

Figure 4. Relative abundance of coho salmon and bluegill before and after chemical rehabilitation of the Tenmile Lakes system in 1968.

Our third question in deciding when to intervene concerns whether it's socially, politically, or legally acceptable. These nonbiological constraints include relative costs: nobody would be willing to pay millions of dollars for pikeminnow bounties unless it's a substitute for more costly measures. Nonbiological constraints include social conventions: can you imagine the uproar if someone proposed a bounty program on Caspian terns? Constraints also include politics: if Oregon removes bag limits on walleye in the Columbia River, does it do any good if Washington doesn't? And of course there are often legal issues: for instance, the Marine Mammal Protection Act limits any nefarious schemes we might entertain if we think seals and sea lions really are a problem. One general rule of thumb addresses these constraints (#5): ***the probability of success is inversely proportional to the number of governmental agencies involved.***

Interaction/Intervention Rules of Thumb

1. ***Perceived interaction problems are often a symptom of an underlying habitat alteration problem.***
2. ***Complex interactions in complex communities often compensate and cancel the benefits of intervention.***
3. ***Intervention benefits will be small unless you can affect most of the problem animals.***
4. ***Benefits will be temporary unless you can sustain the effects.***
5. ***Probability of success is inversely proportional to the number of governmental agencies involved.***

Example Applications

Let's now combine the three-step decision process with the rules of thumb and apply to some examples. The first example is the Pikeminnow bounty program in the Columbia. The interaction is significant because millions of salmonids are being eaten each year. The interaction is not independent of habitat changes because predation is exacerbated by dam construction and operation but the program has been implemented anyway in lieu of more costly changes in the hydropower system. Simple interactions give intervention some chance of success. Interaction is affectable because removals are adequate and sustained. Finally, we can conclude such a program is acceptable since it's already been implemented.

Columbia River Pikeminnow Bounty?		
A. Significant?	Yes	Implement
1) habitat independent?	*No**	
2) simple interaction?	*Yes*	
B. Affectable	Yes	
3) adequate removals?	*Yes*	
4) sustained?	*Yes*	
C. Acceptable?	Yes	

Willamette River Pikeminnow Bounty?		
A. Significant?	No }	No Action
1) habitat independent?		
2) simple interaction?		
B. Affectable		
3) adequate removals?		
4) sustained?		
C. Acceptable?		

The same process leads to a conclusion that there's no need for a bounty program on pikeminnow in the Willamette River. Little smolt predation occurs in the Willamette because it is a relatively unaltered system from a predator-prey behavior point of view. The interaction is not significant and we don't need to go any further because it takes only one "no" to conclude no action.

Unlimited Walleye Fishing - Columbia River?		
A. Significant?	Yes	No Action
1) habitat independent?	*No**	
2) simple interaction?	*Yes*	
B. Affectable	No	
3) adequate removals?	*No*	
4) sustained?	*Yes*	
C. Acceptable?	???	

Unlimited Bass Fishing - Tenmile Lakes?		
A. Significant?	No	No Action
1) habitat independent?	*Yes*	
2) simple interaction?	*No*	
B. Affectable	?	
3) adequate removals?	*?*	
4) sustained?	*Yes*	
C. Acceptable?	?	

Removing all fishing regulations on walleye in the Columbia River is not a promising strategy. Walleye predation is significant but fishing regulations do not remove significant numbers of walleye of predaceous sizes. Anglers don't catch the small walleye that are doing the damage and probably couldn't achieve a high harvest rate even with walleye bounties. The acceptability of a walleye removal program depends on who you ask. There is certainly an active and vocal walleye angling community that would object strenuously to a walleye reduction program.

Similarly, unlimited bass fishing in Tenmile Lakes would not be expected to provide significant benefits. Tenmile Lakes is not a simple system where we can expect a benefit from predator removal. It is questionable whether we could even affect bass predation by increasing harvest rate because bass resemble walleye where most of problem occurs in small fish not subject to fishing. Acceptability issues also limit the likelihood of success. Many bass anglers practice catch and release already and wouldn't keep significantly more bass.

The three-step decision process and rules of thumb illustrate that another chemical rehabilitation of Tenmile Lakes would not provide sustained benefits. The 1968 program showed that treatment can benefit coho, hence we can conclude that species interactions are a significant constraint on coho production. Treatment works in part because it simplifies a complex system. Removals are definitely significant but benefits are not sustained unless treatments are repeated periodically. Further, chemical rehabilitation is much less acceptable in 1998 than it was in 1968.

Chemical Rehabilitation - Tenmile Lakes?		
A. Significant?	Yes	No Action
1) habitat independent?	*Yes*	
2) simple interaction?	*Yes**	
B. Affectable	No*	
3) adequate removals?	*Yes!*	
4) sustained?	*No**	
C. Acceptable?	No	

One last example considers sea lion control at Willamette Falls. Sea lions currently eat several hundred spring chinook and steelhead per year and can cause passage problems if they sit in the ladder entrance. The problem is not habitat independent but no one's proposing removal of all the development at the falls. The interaction is fairly simple, so compensation would not be expected to erode the benefits of intervention. There are only a few problem animals and the lethal removal methods of the past would effective resolve the problem. However, lethal removal of marine mammals is no longer acceptable or legal. Lethal control methods are not an immediate option but nonlethal methods such as gratings might prove effective in keeping animals out of the fish ladder. This example demonstrates that there is often more than one way to address interaction problems and that we can often manage problems indirectly rather than overtly.

Willamette Falls Sea Lion Control?		
A. Significant?	Yes	Maybe
1) habitat independent?	*No**	
2) simple interaction?	*Yes*	
B. Affectable	Yes	
3) adequate removals?	*Yes*	
4) sustained?	*Yes*	
C. Acceptable?	No*	

Conclusions

Summary of Examples	
Action	Intervene?
Pikeminnow bounty - Columbia River	Yes
Pikeminnow bounty - Willamette River	No
Unlimited walleye fishing - Columbia River	No
Unlimited bass fishing - Tenmile Lakes	No
Chemical rehabilitation - Tenmile Lakes	No
Sea Lion Control - Willamette Falls	Maybe

My intention with this paper was to identify an organized method for considering interactions and intervention, and to provide some guidelines for deciding when intervention might be effective and appropriate. The examples addressed illustrate the difficulties of implementing effective intervention programs. The Columbia River pikeminnow bounty program is the lone exception where we think an interaction is significant and affectable, and intervention is acceptable. Clearly, efforts aimed at prevention of undesirable introductions hold greater promise than attempts to affect populations after they become established.

Interaction problems are extremely difficult to diagnose and even harder to affect. Just because one species eats another or uses the same space or food doesn't mean that the interaction is significant. Even when interactions are significant, it's a rare case where intervention will be effective. Perceived interaction problems are often a symptom of underlying habitat alteration problems. Introduced species often do well in altered habitats where native species are poorly-suited and corrective habitat actions are usually more appropriate than fish population manipulations. Even when interactions are significant, intervention benefits are small unless most of the problem animals can be affected and the effect can be sustained. Complex interactions in complex communities may cancel the benefits of intervention or even exacerbate the problem.

Political and social issues compound consideration of any intervention effort and success often hinges not on biology but on public perception. Some might even suggest considering actions with marginal biological benefits in order to affect public perception and stimulate a broader and more effective response. Examples of beneficial intervention can be found but my closing challenge to all who would consider intervention, is to be smart about sorting the real opportunities where we can have an impact from the false cases that look good but accomplish nothing.

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